3-Tesla MRI Non-contrast Vessel Wall Imaging in Young, Healthy Adults and Moyamoya Patients

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Target Audience: Researchers interested in non-contrast vessel wall imaging at clinically-available field strengths.

Introduction: The purpose of this work is to present a non-contrasted vessel wall imaging (VWI) protocol, recently adapted from 7T MRI, at the clinically-available field strength of 3T and to evaluate specificity in patients with intracranial (IC) vessel wall disease and age-matched healthy volunteers. We specifically seek to understand the reliability of VWI in depicting the anatomy of the major IC arteries and general differences in vessel wall morphology between patients with moyamoya disease and controls. VWI is a critical first step in understanding intracranial plaque morphology and distribution as well as possible plaque remodeling with treatment. For non-atherosclerotic IC vascular diseases, VWI may help confirm suspected diagnosis and provide a noninvasive method for longitudinal studies of pathology. Currently, the gold standard for neurovascular imaging is digital subtraction angiography (DSA). However, this technique is invasive and insensitive to arterial wall remodeling, which preserves luminal patency despite vessel wall thickening. Therefore, there is a need for a noninvasive method capable of characterizing the pathological processes underlying vessel wall changes which can be performed during routine clinical scans. We show that this can be achieved clinically at 3T within a short (< 7 min) scan time while maintaining an adequate signal-to-noise ratio (SNR), spatial resolution, and field-of-view (FOV).

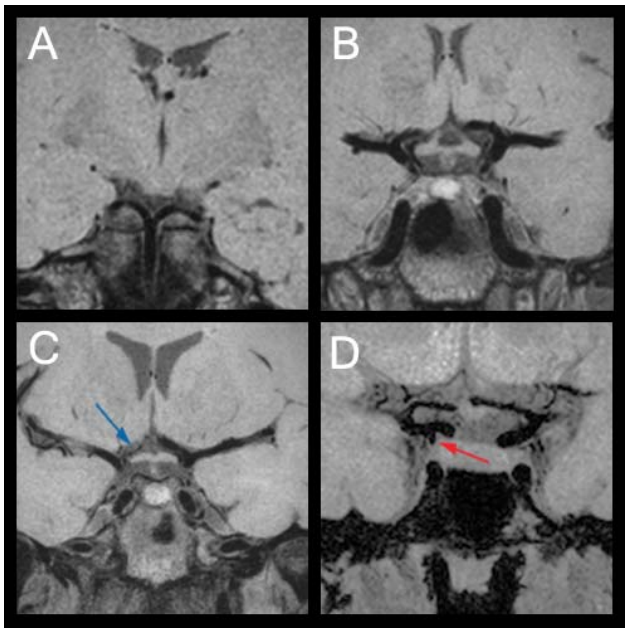

Fig. 1. Visualization of the COW anatomy in healthy controls using 3T VWI. A) Basilar artery branching into posterior cerebral arteries (PCA). B) Terminal internal carotid arteries dividing into anterior cerebral arteries (ACA) and middle cerebral arteries. C) Hypoplastic A1 segment of the ACA (blue arrow). D) 2.5mm PCA aneurysm (red arrow).

Methods: All volunteers provided informed, written consent. Healthy volunteers (n=10; age=26.5±3.1 yrs; 5M/5F) without known cardiovascular or cerebrovascular disease underwent either 3D Time-of-Flight (TOF) or phase-contrast (PC) MRA, as well as VWI (Philips Achieva 3T). Moyamoya patients (n=6; age=49.0±18.6 yrs; 1M/5F) underwent the same VWI protocol within ±40 days of DSA. 3D T1 gradient echo (GRE) TOF MRA images were obtained in the axial plane: TR/TE=13.4ms/1.7ms; field-of-view (FOV)=200mm x 200mm. 3D Phase Contrast (PC)-MRA was obtained with a similar resolution and TR/TE=6.4ms/3.6ms. 3D PC-MRA allowed for faster scan times compared to TOF MRA and was used only for sequence planning and identifying the major IC vessels. VWI was acquired in the coronal plane using a 3D turbo spin echo (TSE) T1w sequence with a long TSE readout, which served to null the flowing blood water. CSF water signal suppression was achieved using an anti-driven equilibrium module consisting of a +90 RF pulse in combination with a gradient refocusing pulse and spoiler gradient, which reduces the steady-state CSF magnetization. VWI spatial parameters include: FOV=45cmx166cm^2; spatial resolution=0.6x0.6x1mm^3, TR/TE=1500ms/38.5ms, scan duration=6min 51s. Two board-certified neuroradiologists independently reviewed all MRA and VWI images. To avoid bias in measurements, both reviewers delayed the evaluation of the second of the two imaging sequences by at least five days. A quantitative comparison in the lengths of the right and left M1 between measurements acquired with MRA and VWI were calculated for 9 of 10 controls using Lin's Concordance Correlation Coefficient[1]; one volunteer was excluded due to poor image quality of the distal vessels. MCA bifurcation measures were performed separately then agreed upon in consensus.

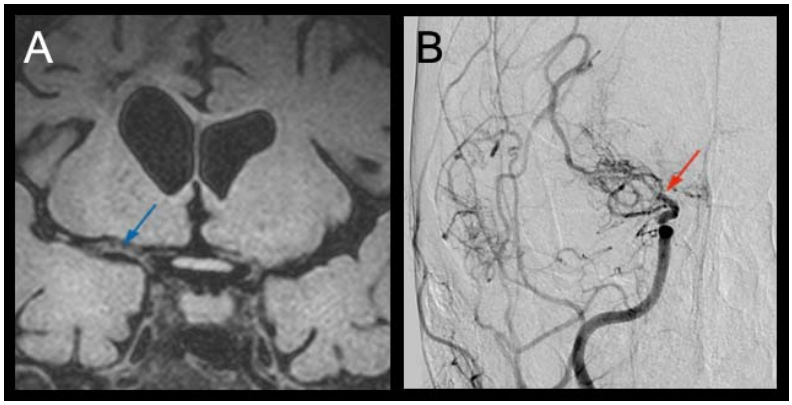

Fig. 2. 50 y/o F moyamoya patient with significant bilateral terminal ICA and MCA disease. A) VWI showing vessel wall of R M1 with significant thickening but preserved luminal patency (blue arrow). B) DSA (AP projection from R CCA injection) demonstrates severe stenosis (red arrow) with distal collateralization and recanalization of the R MCA.

Results and Discussion: Cohen's kappa statistics for inter-observer reliability in determining Circle of Willis (COW) anatomy with MRA and VWI were 0.846 (95% CI 0.636-1.056) and 0.731 (95% CI 0.504-0.958), respectively. Intra-observer reliability kappa statistics for readers between MRA and VWI for COW anatomy were 0.815 (95% CI 0.611-1.020) and 0.757 (95% CI 0.5226-0.988), respectively. The average length of the right M1 using VWI and MRA, respectively, was 20.526±4.887 mm and 21.302±4.275 mm; for the left it was 21.067±4.786 mm and 19.670±4.677 mm, respectively. Concordance correlation coefficients for the right and left M1 were 0.910 (95% CI 0.680-0.979) and 0.950 (95% CI 0.857-0.983), respectively. **Figure 1** shows VWI findings for four young, healthy volunteers; **Figure 2** demonstrates VWI and DSA findings for a subject with moyamoya disease. Our primary results demonstrate that VWI at 3T MRI can provide the tissue contrast required for the reliable identification of both normal and variant COW anatomy, as well as of the arterial branching points distal to the COW. A secondary finding is that it is possible to visualize the vessel walls of young, healthy volunteers at 3T. Despite the multiple planes across which the COW vessels traverse, it was possible to identify the presence, absence, or variance of the major COW vessels of every participant. Furthermore, we were able to track the distal M1 and proximal M2 arteries a considerable distance away from the COW. While vessel wall changes in the elderly and IC disease are well documented[2,3], there has been considerable difficulty in visualizing young, healthy vessel walls[4] due to both a lack of parenchymal atrophy allowing for greater contrast against CSF as well as a lack of pathological changes in arterial walls. The current data indicate that the identification of healthy vessel walls, which is crucial for understanding the progressive changes undergone by a diseased wall, is feasible with our parameters.

Conclusion: We demonstrate that VWI performed at 3T can provide an excellent image quality for the discernment of vessel wall morphology of the IC arteries within and distal to the COW in the absence of intravenous contrast administration in both healthy controls and in patients with cerebrovascular disease.

References: 1.Lin LI. *Biometrics*. 1989;45:255-268; 2.Swartz RH et al..*Neurology*. 2009;72:627-634 3.Li ML et al. *Atherosclerosis*. 2009;204:447-452; 4.van der Kolk AG et al. *Stroke*. 2011;42:2478-2484. Funding for this project was supported by AHA award 14PRE20370055 and NIH/NINDS 5R01NS078828.